# ENVIRONMENTAL FATE OF CONTAMINANTS FROM SLUDGE DISPOSAL ALTERNATIVES TO OCEAN DUMPING

## Incineration Report

AQUA TERRA CONSULTANTS
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# ENVIRONMENTAL FATE OF CONTAMINANTS FROM SLUDGE DISPOSAL ALTERNATIVES TO OCEAN DUMPING

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by

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# ABSTRACT

The EPA Office of Policy, Planning, and Evaluation is conducting a cross-media analysis of proposed revisions to the ocean dumping regulations to evaluate the environmental impacts of land-based alternatives to ocean disposal of sewage sludge. A model has been developed for comparing the environmental risks and costs of major disposal options including land application, landfilling, incineration, distribution and marketing, and ocean disposal. This model requires the input of unit concentrations of contaminants in ground water, surface water, and air for all exposure pathways identified for each disposal alternative. These unit values are the environmental concentrations produced by a unit (e.g., 1000 kg/ha/yr) rate of sludge disposal; concentrations for other disposal rates increase linearly as a function of the disposal rate. These environmental concentrations provide the basis for performing the comparative risk and cost-effectiveness assessment in the model.

This report describes and demonstrates the methodology developed for estimating the unit air concentrations of chemicals resulting from incineration of municipal sludge. The methodology utilizes a point source atmospheric dispersion model to calculate contaminant concentrations under regional meteorologic site conditions, and typical sludge incineration design and operating procedures. The report includes a model description, discussion of the methodology assumptions and procedures for modeling sludge incineration, and results of case study applications in New York and Florida.

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For AQUA TERRA Consultants, Mr. Brian Bicknell was the Project Manager and key technical staff person. He developed the modeling methodology, estimated required parameters, executed the ISCLT model runs, analyzed the results, and wrote the project report. Mr. Anthony Donigian was the Project Director providing overall technical direction, review, and administrative support. Report word processing was performed by Ms. Dorothy Inahara, and figures were prepared by Ms. Marythomas Hutchins. The contributions and support from all these individuals is sincerely appreciated.

## SECTION 1.Ø

## INTRODUCTION

The ocean dumping regulations are being revised to include provisions for the use of cross media analysis (CMA) in evaluating ocean dumping permit applications. CMA will be used to establish relative risk to human health and the environment and the relative costs of the use of ocean and land-based disposal alternatives. Ocean disposal will be allowed if an applicant can demonstrate that no safer land-based alternative exists at a reasonable incremental cost.

In 1981, U.S. District Court Judge Abraham Sofaer ruled that the EPA could not prohibit the ocean dumping of sewage sludge that violated marine water quality criteria without considering whether available land-based disposal options are environmentally less preferable. To comply with this decision, EPA's proposed revisions to the ocean dumping regulations would allow a permittee to dump wastes in the ocean if no practicable disposal alternative with less total impact on the environment is available.

The EPA Office of Policy Analysis' Integrated Environmental Management Division (IEMD) has developed a model for comparing the risks and costs of disposing sewage sludge among major disposal options. The IEMD Sludge Analysis Model provides for a national analysis which identifies high risk areas either in terms of contaminants or disposal practices and develops a profile of the disposal options in terms of the cost-effectiveness of reducing risk. The model requires the input of unit concentrations of contaminants in ground water, surface water, and air for all exposure pathways identified for each disposal alternative. For incineration, these unit values are the environmental concentrations produced by a unit (e.g., 1 g/s) rate of chemical emission from the incinerator stack; concentrations for other disposal rates increase linearly as a function of the disposal rate. These environmental concentrations provide the basis for performing the comparative risk and cost-effectiveness assessment in the model.

## 1.1 OBJECTIVE AND SCOPE

The objective of this study is to determine the environmental unit concentrations required for the IEMD Sludge Analysis Model by performing an environmental fate assessment of selected sludge contaminants and disposal practices. The scope of this effort includes the disposal practices and associated exposure media and pathways listed below:

| Disposal Alternative | Environmental Exposure Media |
|---|---|
| Landfill | Ground Water |
| Land Application | Surface Water, Ground Water |
| Incineration | Air |

For each disposal alternative, the contaminants of concern have been identified by U.S. EPA (1985a) and are listed in Table 1.1; these include both organic and inorganic compounds. Thus, for each disposal alternative and exposure media, unit concentrations are needed for each contaminant included in Table 1.1 resulting from a unit disposal rate.

The analysis is designed to be performed on a regional basis by defining "representative" environmental, edaphic, and hydrogeologic conditions for coastal areas where applications for ocean dumping permits may be likely. Approximately, six coastal regions, including three on the East Coast, two on the West Coast, and one on the Gulf Coast may be needed to provide adequate coverage of the coastal U.S. For each representative coastal region, mathematical models will be used to assess contaminant fate and estimate unit environmental concentrations. Meteorologic input and model parameters will be derived to represent likely conditions - climate, soils, topography, hydrogeology - in each region.

The assembled methodology will also be available to be applied by an applicant for a specific site if required.

This report describes our approach to the assessment of the air exposure pathway for sludge incineration, including an overview of the methodology, a summary of the application and results, and a brief description of the model and required input parameters. Section 2.Ø provides the methodology overview, while Section 3.Ø describes the methodology application and results. The model is described briefly in Section 4.Ø, along with the model input data and parameters.

TABLE 1.1 CONTAMINANTS OF CONCERN (By Disposal Option)

| Dedicated Land Application/ Landfilling | Incineration |
|---|---|
| Arsenic | Aldrin |
| Benzene | Arsenic |
| Benzo(a)pyrene | Benzo(a)pyrene |
| Chlordane | Beryllium |
| Copper | Cadmium |
| Cyanide | Chlordane |
| DDT | Chromium |
| DEHP | DEHP |
| Dimethylnitrosamine | Lead |
| Lead | Nickel |
| Lindane | PCBs |
| Mercury | Toxaphene |
| Nickel | Vinyl Chloride |
| PCBs | |
| Trichloroethylene | |
| Toxaphene | |

## SECTION 2.0

## INCINERATION METHODOLOGY

### 2.1 INCINERATION METHODOLOGY OVERVIEW

The incineration methodology utilizes the point-source, atmospheric dispersion model ISCLT to estimate average annual ground-level concentrations of contaminants at various distances from the incinerator. The ISCLT model was chosen because it is an EPA approved model, and because of its use in other EPA sludge incineration studies (EPA, 1985b; MacArthur et al., 1986). The model uses a steady-state Gaussian plume equation for a continuous source in flat terrain. Meteorologic input data for ISCLT consist of annual statistical summaries of wind speed, wind direction, and Pasquill-Gifford stability categories for each of sixteen compass point directions. Receptors are given on polar or cartesian coordinate systems, and are generally located between 100 m and 50 km of the source.

A diagram showing the methodology is shown in Figure 2.1. The methodology is similar to that utilized by EPA Office of Water Regulations and Standards (OWRS) to assess human health and environmental impacts resulting from incineration of municipal sewage sludge (EPA, 1985a,b). In this methodology, the emission rate of a specific contaminant from the incinerator is determined by the sludge input rate (MT/day), the contaminant concentration in sludge (mg/kg), and the fraction of contaminant loading emitted from the stack. The actual ground-level concentrations at various points downwind of the facility are determined by multiplying these contaminant-specific emission rates by the concentrations predicted by ISCLT using a unit (1.0 g/s) emission rate. Contaminant-specific processes such as degradation and deposition are neglected; and since multiple sources (stacks) are not considered, the predicted ground-level concentrations are linear with respect to emission rates.

In addition to the emission rate, other source-related parameters are the stack height and diameter, stack gas exit temperature, and exit velocity. In the OWRS methodology, six actual plants located in various parts of the country were selected. Data from these facilities provided input to a series of standard heat and mass balance calculations (for incinerators) which yielded the exit temperatures and velocities. In the current methodology, a

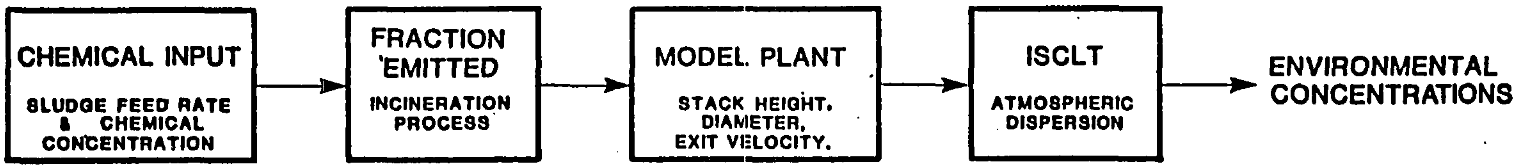



Figure 2.1 Flow chart for incineration methodology.

series of model plants were modeled at each site, and representative values of the source parameters listed above were selected from an EPA (1985c) database of sludge incinerators.

ISCLT model executions were performed using the EPA Office of Toxic Substances GEMS computer facility. A polar coordinate receptor network consisting of sixteen compass direction sectors and ring distances of 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, and 50 km was selected. Meteorologic input to the model, in the form of STAR data summaries, are accessible online for a large number of locations in the U.S., and are selected to be representative of the appropriate regions.

## 2.2 INCINERATION SCENARIO

### 2.2.1 Chemical Concentrations in Sludge

Since contaminant concentrations in sludge are highly variable, this methodology uses a unit contaminant concentration which allows the flexiblity to adjust the resulting environmental concentrations by any desired sludge contaminant concentration. Table 2.1 shows the results of a recent comprehensive EPA (1985b) survey of POTW sludge quality as well as compilations from several other studies (Fricke and Clarkson, 1984). Table 2.2 lists typical and worst-case values adopted by EPA (1985b) in the OWRS study.

### 2.2.2 Fraction of Chemical Emitted From the Stack

Atmospheric emissions of contaminants from incinerators result from 1) the mass of contaminant in the sludge, 2) the fraction contained in the flue gas (gaseous and particulate), and 3) the fraction removed by the air pollution controls. The latter two factors are determined largely by combustion temperature and scrubber efficiency. In this methodology, the effects of these two factors are included in an overall "fraction of contaminant emitted from the stack," and a unit value is used to allow flexibility to adjust the environmental concentrations by any desired emission fraction. Typical and worst-case values adopted by EPA (1985b) in the OWRS study are also shown in Table 2.2. The data for metals are based on measurements and estimates by Farrell and Wall (1981) and Farrell (1985) for ten sewage sludge incinerators operating at conventional temperatures. Additional values for higher temperature incinerators have been compiled from the literature by Gerstle and Albrinck (1982). In the absence of significant data for organic chemicals, the OWRS

TABLE 2.1 CONCENTRATIONS OF SELECTED POLLUTANTS IN SLUDGE: EPA SURVEY AND OTHER SURVEYS

| POLLUTANT | EPA POTW SURVEY (Concentrations in mg/kg dry wt.) MEAN | MEDIAN | MINIMUM | MAXIMUM | OTHER STUDIES AND SURVEYS (mg/kg dry wt.) WT.MEAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|---|---|---|
| METALS AND CYANIDE | | | | | | | |
| Arsenic | 5.9 | 4.7 | 0.33 | 27.5 | 10.6 | 0.3 | 50 |
| Beryllium | 1.2 | 0.47 | 0.16 | 10.0 | 0.6 | 0.2 | 3.4 |
| Cadmium | 32.2 | 8.3 | 0.38 | 612.8 | 43.7 | <1 | 1200 |
| Chromium | 427.9 | 252.9 | 22.6 | 1904.8 | 785.1 | 6 | 35900 |
| Cobalt | | | | | 14.6 | 3.9 | 27.9 |
| Copper | 562.4 | 380.9 | 36.1 | 2970.6 | 909.7 | 22 | 7700 |
| Lead | 378.0 | 246.0 | 32.8 | 1627.2 | 519.9 | 10 | 28200 |
| Mercury | 2.8 | 2.0 | 0.01 | 11.3 | 4.6 | 0.6 | 130 |
| Molybdenum | | | | | 8.3 | 4.5 | 11.6 |
| Nickel | 133.9 | 70.4 | 3.1 | 803.3 | 216.9 | 4 | 13000 |
| Selenium | 2.6 | 1.4 | 0.14 | 28.2 | 2.0 | 0.21 | 25 |
| Zinc | 1409.2 | 769.4 | 169.9 | 8467.7 | 2194.0 | 29.7 | 34300 |
| Cyanide | 748.5 | 423.1 | 0.29 | 5018.7 | 84.4 | 6.8 | 150 |
| VOLATILE COMPOUNDS (PURGEABLE) | | | | | | | |
| Benzene | 1.46 | 0.34 | 0.03 | 17.0 | NA | 0.002 | 0.170 |
| Carbon tetrachloride | 4.48 | 2.42 | 0.17 | 12.9 | NA | 0.155 | 0.155 |
| Chlorobenzene | 1.16 | 0.29 | 0.02 | 12.9 | 55.4 | 0.0065 | 846 |
| Chloroform | 0.85 | 0.23 | 0.02 | 10.1 | NA | 0.004 | 0.150 |
| 1,2-Dichloroethane | 25.03 | 0.29 | 0.06 | 201.5 | NA | 0.022 | 0.022 |
| Methylene chloride | 8.65 | 1.62 | 0.02 | 195.3 | 1.22 | 0.075 | 2.666 |
| Tetrachloroethylene | 3.47 | 0.68 | 0.02 | 42.1 | <0.01 | 9.62E-06 | 2.8 |
| Toluene | 1718.8 | 16.2 | 0.77 | 68643.9 | 17.77 | 0.214 | 2400 |
| Trichloroethylene | 9.10 | 1.84 | 0.05 | 193.9 | NA | 0.001 | 0.466 |
| Vinyl chloride | 35.4 | 11.9 | 2.9 | 110.2 | NA | 0.045 | 0.045 |
| ACID COMPOUNDS (ACID EXTRACTABLE) | | | | | | | |
| Pentachlorophenol | 10.4 | 3.9 | 0.17 | 91.1 | 81.1 | 0.17 | 8490 |
| Phenol | 19.3 | 7.5 | 0.16 | 113.4 | 9.1 | 0.0166 | 288 |
| 2,4,6-Trichlorophenol | 2.3 | 2.3 | 0.04 | 4.6 | 42.3 | 0.195 | 1330 |

NA = Not available

Notes: Means, medians, and ranges are for concentrations where detected only.
Weighted means include Michigan, New York City, Indiana, Galveston, Albuquerque, and Phoenix surveys only.
9.62E-06 = 0.00000962

SOURCE: EPA, 1985b

(continued)

TABLE 2.1 Continued

| POLLUTANT | EPA POTW SURVEY (Concentrations in mg/kg dry wt.) MEAN | MEDIAN | MINIMUM | MAXIMUM | OTHER STUDIES AND SURVEYS (mg/kg dry wt.) WT.MEAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|---|---|---|
| BASE/NEUTRAL COMPOUNDS (BASE/NEUTRAL EXTRACTABLE) | | | | | | | |
| Benzidine | | | | | 12.7 | 2.575 | 12.7 |
| Benzo(a)anthracene | 9.1 | 0.81 | 0.03 | 177.4 | 1.53 | 0.67 | 9.850 |
| Benzo(a)pyrene | 256.6 | 0.61 | 0.09 | 1279.1 | 1.34 | 0.40 | 9.00 |
| Benzo(b)fluoranthene | 1.76 | 1.02 | 0.02 | 6.0 | 3.28 | 1.34 | 5.04 |
| bis(2-Ethylhexyl) phthalate | 157.6 | 101.3 | 4.1 | 764.0 | 1169.5 | 0.14 | 58300 |
| Chrysene | 8.3 | 1.01 | 0.03 | 177.4 | 2.20 | 0.87 | 4.74 |
| 3,3'-Dichloro-benzidine | 1.64 | 1.64 | 0.98 | 2.29 | 3.13 | 2.76 | 3.5 |
| Hexachlorobenzene | 1.25 | 0.92 | 0.37 | 2.31 | 468.0 | <0.13 | 26200 |
| Hexachlorobutadiene | 4.5 | 4.5 | 0.92 | 8.0 | 0.22 | 9.24E-05 | 3.74 |
| n-Nitrosodi methylamine | 0.04 | 0.04 | 0.04 | 0.04 | NA | NA | NA |
| Phenanthrene | 5.9 | 4.0 | 0.04 | 30.1 | 0.18 | 0.10 | 43.5 |
| Pyrene | 6.8 | 2.1 | 0.08 | 164.1 | NA | 0.141 | 0.338 |
| PESTICIDES AND PCB'S | | | | | | | |
| Aldrin | ND | ND | ND | ND | 0.15 | 0.01 | 0.64 |
| Gamma-BHC (Lindane) | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.02666 | 0.22 |
| Chlordane | ND | ND | ND | ND | 3.01 | 0.0170 | 12 |
| 2,4-D | | | | | 4.64 | 2.12 | 7.16 |
| 4,4'DDT | ND | ND | ND | ND | 0.28 | 0.06 | 0.93 |
| 4,4'DDE | 0.06 | 0.06 | 0.06 | 0.06 | 0.25 | 0.00058 | 0.47 |
| 4,4'-DDD | ND | ND | ND | ND | 0.21 | 0.081 | 0.50 |
| Dieldrin | 0.02 | 0.02 | 0.02 | 0.02 | 0.08 | 0.0006 | 0.81 |
| Endrin | ND | ND | ND | ND | NA | 0.11 | 0.17 |
| Heptachlor | 0.02 | 0.02 | 0.02 | 0.02 | 0.10 | 0.09 | 0.10 |
| Malathion | | | | | 0.63 | 0.63 | 0.63 |
| PCB's | ND | ND | ND | ND | 29.06 | 0.0015 | 620 |
| Toxaphene | ND | ND | ND | ND | 7.88 | 4.69 | 10.79 |
| OTHERS | | | | | | | |
| Flouride | | | | | 3091 | 106.8 | 7500 |
| Tricresyl phosphate | | | | | 39.9 | 0.0690 | 1650 |

BHC = Benzene hexachloride DDT = Dichlorodiphenyltrichlorethane
DDE = Dichlorodiphenyldichloroethylene DDD = Dichlorodiphenyldichloroethane
NA = Not available ND = Not detected

Notes: Means, medians, and ranges are for concentrations where detected only. Weighted means include Michigan, New York City, Indiana, Galveston, Albuquerque, and Phoenix surveys only.

SOURCE: EPA, 1985b

TABLE 2.2 CONTAMINANT CONCENTRATION AND FRACTION EMITTED THROUGH STACK - OWRS INCINERATION METHODOLOGY

| Contaminant | Concentration (μg/g) | | Fraction Emitted | |
|---|---|---|---|---|
| | Typical | Worst | Typical | Worst |
| Aldrin | 0.22 | 0.81 | 0.05 | 0.20 |
| Benzo(a)pyrene | 0.143 | 1.937 | 0.05 | 0.20 |
| Chlordane | 3.2 | 12.0 | 0.05 | 0.20 |
| DEHP | 94.28 | 459.25 | 0.05 | 0.20 |
| PCBs | 4. | 23. | 0.05 | 0.20 |
| Toxaphene | 7.88 | 10.79 | 0.05 | 0.20 |
| Vinyl Chloride | 0.43 | 311.94 | 0.05 | 0.20 |
| Arsenic | 4.6 | 20.77 | 0.30 | 0.40 |
| Beryllium | 0.313 | 1.168 | 0.01 | 0.03 |
| Cadmium | 8.15 | 88.13 | 0.30 | 0.40 |
| Chromium | 230.1 | 1499.7 | 0.003 | 0.006 |
| Lead | 248.2 | 1070.8 | 0.04 | 0.10 |
| Nickel | 44.7 | 662.7 | 0.002 | 0.006 |

methodology adopted "best approximations" of the emission fractions. These values are included in Table 2.2.

### 2.2.3 Model Plant Selection

Model incinerators were developed to provide the input parameters needed for performing the air dispersion modeling. These model incinerators were developed from data representative of actual incineration facilities. The EPA (1985c) Office of Air Quality Planning and Standards compiled a data base of POTW incinerators in the U.S. This database contains information on most design and operational parameters of incinerators required for defining them as point sources in air dispersion modeling. These variables include incineration type, sludge capacity, stack parameters (height, diameter, exit velocity), building dimensions, type of pollution control equipment, location (for meteorologic data input), and the terrain and population around the site.

For purposes of this analysis and use of the ISCLT model, the following variables are necessary:

- Capacity
- Stack height
- Stack diameter
- Exit velocity
- Exit temperature
- Location

Distributions of capacity, stack height and diameter, and exit velocity are shown in Figure 2.2. Since this methodology uses a unit value of sludge feed rate (i.e., the user adjusts the results for any desired incinerator capacity), capacity is not a required variable for the actual modeling; however, 3 model plant capacities were selected as representative. The temperature distribution is not shown since most values were identical (322$^{o}$K). Based on the distributions shown in Figure 2.2, the following values were selected to represent each of the variables:

| | |
|---|---|
| Capacity | 10 MT/day |
| | 40 MT/day |
| | 300 MT/day |
| Stack Height | 10 m |
| | 20 m |
| | 45 m |
| Stack Diameter | 1 m |
| Exit Velocity | 3 m/s |
| | 16 m/s |

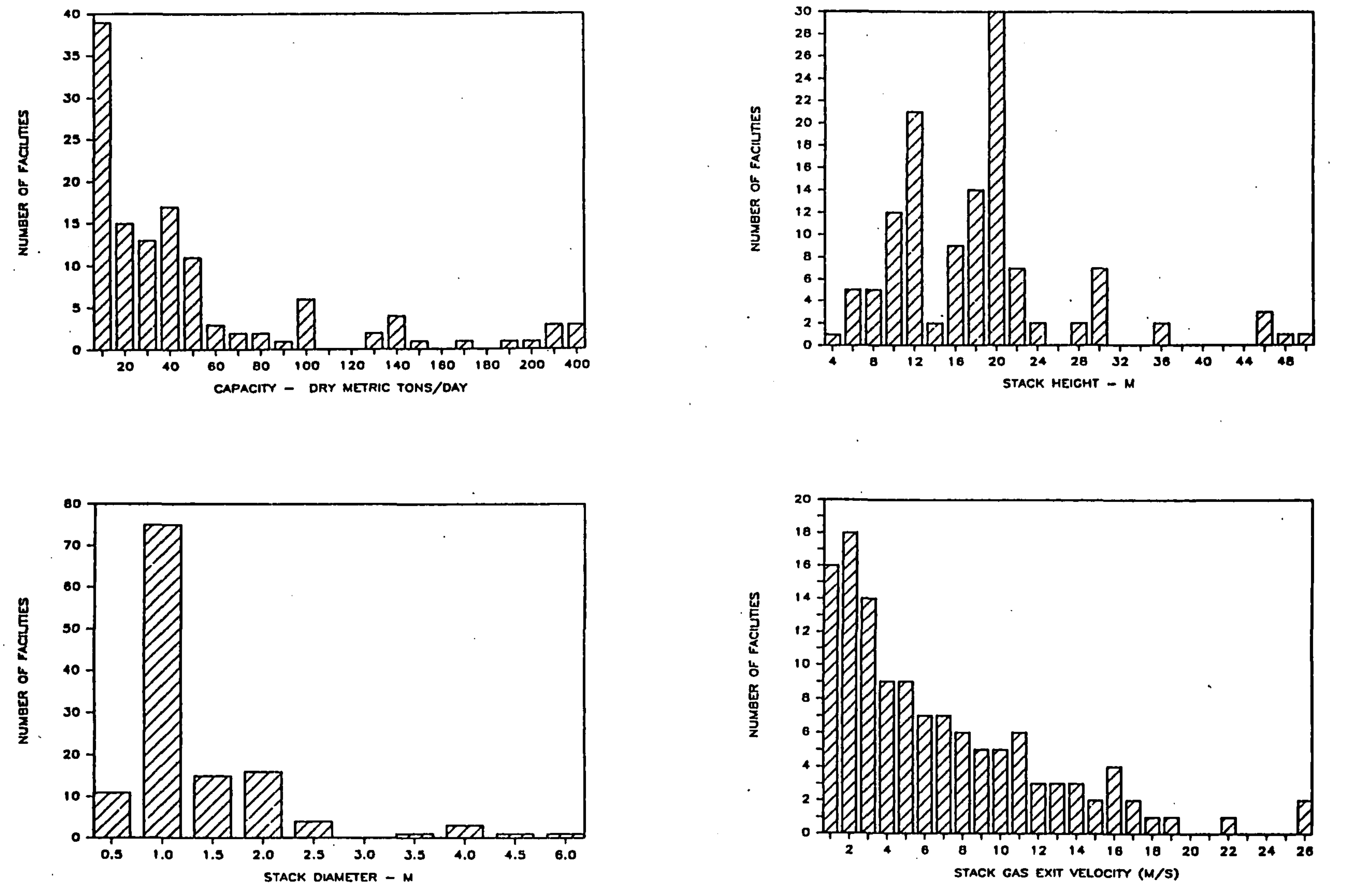



Figure 2.2 Distributions of incinerator facilities - capacity, stack height, stack diameter, and stack gas exit velocity.

Since there is little correlation between parameters, all possible combinations were modeled, providing a series of model plants which represent most existing POTW sludge incinerators.

### 2.2.4 Atmospheric Dispersion Modeling

Atmospheric dispersion modeling of incineration stack sources was performed using the steady-state Gaussian plume model ISCLT. This model has been summarized above (Section 2.1) and is described in detail in Section 4. ISCLT assumes a continuous source located in flat terrain. Several optional features in ISCLT are not utilized in this methodology. In particular, the effect of building aerodynamics on plume downwash is ignored in this non-site specific analysis. Neglect of this effect should be considered carefully since many sludge incinerators have short stacks and little plume rise (MacArthur et al., 1986), and are thus subject to building aerodynamics effects.

Other assumptions specific to this analysis are the use of a single stack at each facility, and neglect of plume losses due to deposition and chemical degradation; ignoring these chemical attenuation processes will lead to conservative unit concentration estimates. The use of ISCLT also precludes the consideration of receptor point elevations greater than the stack height; however, the assumption of flat terrain is reasonable for the coastal areas modeled in this analysis.

### 2.2.5 Methodology Summary and Assumptions

The incineration methodology and the key assumptions inherent in this methodology are summarized as follows:

- ISCLT atmospheric dispersion model used to compute long-term (yearly average) ground-level concentrations based on constant source rate incinerators.

- Source parameters (stack dimensions, stack gas exit velocity, etc.) defined by a series of model incineration facilities based on a database of incinerators across the U.S.

- Unit concentrations (based on unit sludge feed rate, sludge chemical concentration, and fraction of chemical emitted) are adjusted by the user for a specific situation.

- No effect of buildings on plume.

- No plume losses caused by deposition or degradation.
- Level terrain and all terrain is lower than the stack.

## 2.3 ADJUSTMENT OF UNIT CONCENTRATIONS

The unit concentrations computed by the model correspond to a source rate of 1 g/s; consequently, they must be adjusted for specific facility size and chemical scenarios. Each unit ground-level atmospheric concentration is a direct linear function of three factors: 1) the sludge feed rate, 2) the sludge chemical concentration, and 3) the fraction of chemical emitted from the stack. Thus, the predicted environmental concentrations for a particular scenario may be computed as follows:

$$AC = CF * SR * SC * FE * UA \qquad (2\text{-}1)$$

where AC = adjusted ground-level atmospheric concentration ($\mu g/m^3$)

SR = sludge feed rate (dry metric tons/day)

SC = sludge chemical concentration (mg/kg)

FE = fraction of chemical emitted (-)

CF = 1.157E-5 = conversion factor to correct the time and mass units; this normalizes the concentration for

SR = SC = FE = 1.Ø

UA = unit concentration corresponding to 1 g/s emission rate ($\mu g/m^3$)

## SECTION 3.Ø

## CASE STUDY APPLICATIONS - NEW YORK AND FLORIDA

ISCLT was executed for the New York and Florida coastal areas using facility parameters described in Section 2.2, a source rate equal to 1 g/s, and meteorologic data for the appropriate regions. STAR data sets containing meteorologic data for ISCLT were selected from those avilable on the EPA Office of Toxic Substances GEMS computer system. The two data sets are summarized as follows:

| STATION NAME | LATITUDE | LONGITUDE | PERIOD OF RECORD |
|---|---|---|---|
| New York - Laguardia, NY | N 4Ø 46 | W 73 54 | 1965-7Ø |
| Orlando - Jetport, FL | N 28 27 | W 81 18 | 1941-74 |

Ground-level concentrations were computed by the model at a network of receptor points out to a distance of 5Ø km. The receptor points corresponding to distances from Ø.1 to 1. km are located at the midpoints of the arc segments shown in Figure 3.1. For each scenario modeled, the concentrations along the compass direction which exhibited the highest values were chosen to represent the scenario. Figure 3.1 shows the direction or sector having the highest concentrations for the New York and Florida case study applications. Table 3.1 lists the resulting unit concentrations out to 5Ø km for all facility scenarios. As expected, scenarios with lower stack heights and exit velocities result in higher environmental concentrations. In order to illustrate the variations with distance, stack height, and stack exit velocity, the concentrations from Ø.1 to 5 km are shown in Figure 3.2.

The unit concentrations shown in Table 3.1 must be adjusted for the specific incinerator capacity and chemical scenarios. This calculation is described in Section 2.3, and is illustrated in the following example:

Scenario

300 MT/day incinerator located near the coast in New York

Stack height = 1Ø m

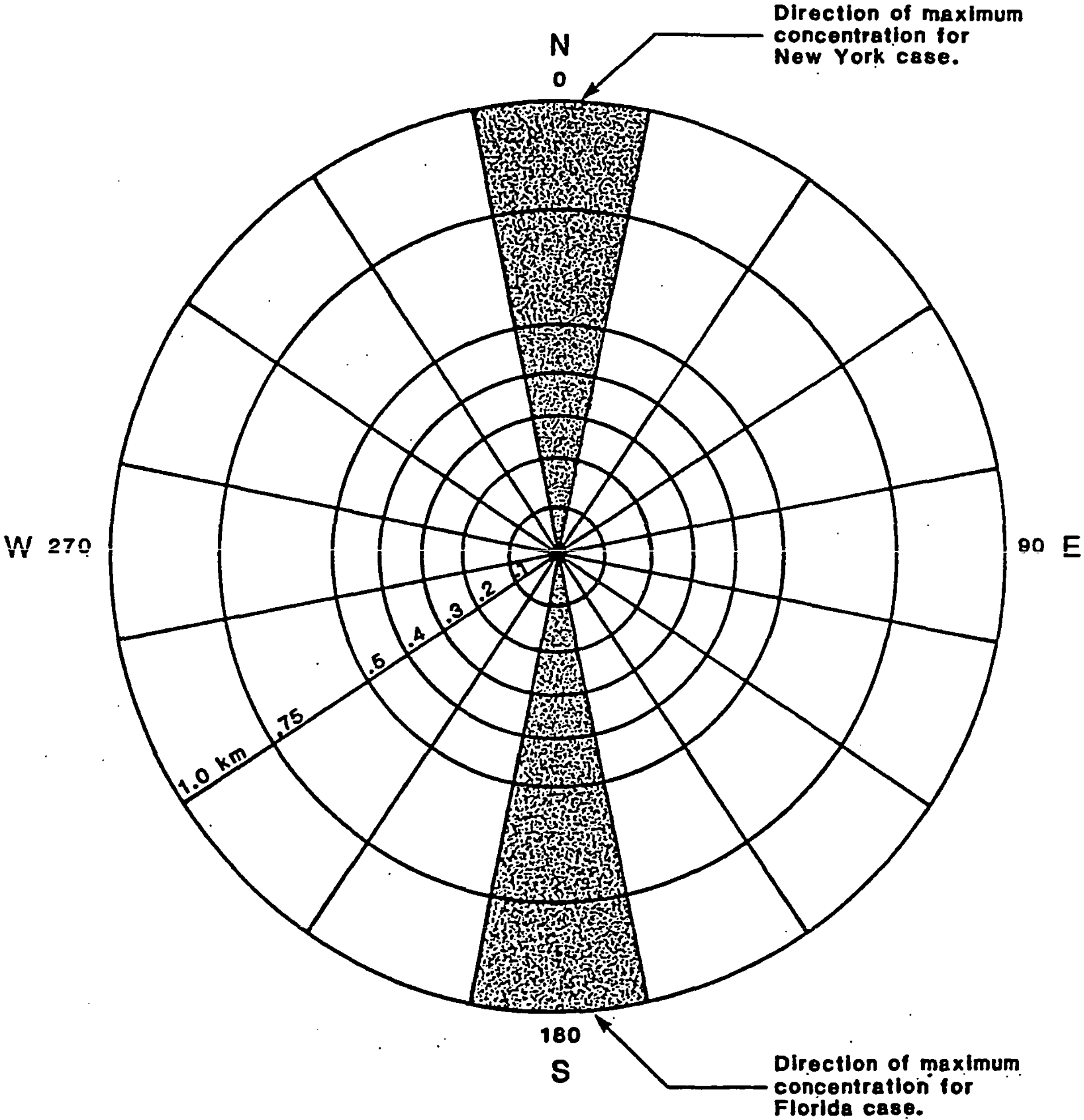


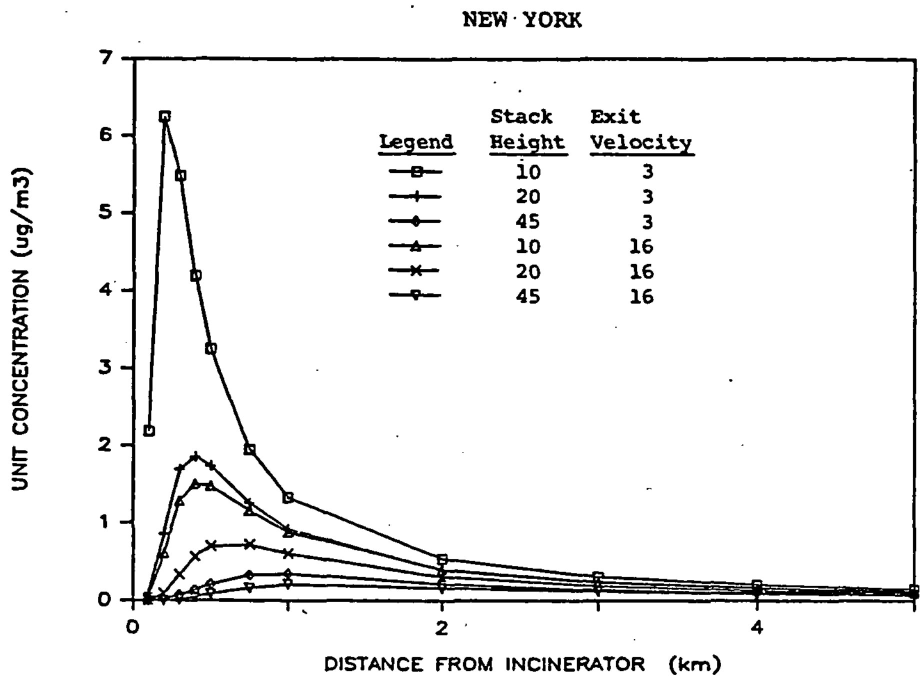

Figure 3.1 Polar Coordinate Receptor Diagram and maximum concentration directions for New York and Florida case study applications.

# TABLE 3.1 ISCLT UNIT CONCENTRATIONS

CONCENTRATION FROM ISCLT (1) (ug/m3)

| STACK HEIGHT (m) | STACK EXIT VEL. (m/s) | DISTANCE FROM STACK (km) 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.75 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 10.0 | 15.0 | 20.0 | 25.0 | 50.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NEW YORK | | | | | | | | | | | | | | | | | |
| 10 | 3 | 2.19 | 6.25 | 5.49 | 4.20 | 3.25 | 1.95 | 1.33 | 0.54 | 0.31 | 0.20 | 0.15 | 0.055 | 0.030 | 0.020 | 0.015 | 0.0057 |
| 20 | 3 | 0.086 | 0.87 | 1.70 | 1.86 | 1.74 | 1.26 | 0.92 | 0.40 | 0.23 | 0.16 | 0.11 | 0.042 | 0.024 | 0.016 | 0.012 | 0.0045 |
| 45 | 3 | 1E-05 | 0.018 | 0.078 | 0.14 | 0.21 | 0.33 | 0.35 | 0.21 | 0.14 | 0.098 | 0.074 | 0.030 | 0.017 | 0.011 | 0.0084 | 0.0033 |
| 10 | 16 | 0.033 | 0.61 | 1.29 | 1.51 | 1.48 | 1.16 | 0.88 | 0.40 | 0.24 | 0.17 | 0.13 | 0.049 | 0.028 | 0.019 | 0.014 | 0.0055 |
| 20 | 16 | 0.0008 | 0.094 | 0.34 | 0.57 | 0.70 | 0.72 | 0.61 | 0.31 | 0.19 | 0.13 | 0.098 | 0.039 | 0.022 | 0.015 | 0.011 | 0.0043 |
| 45 | 16 | 1E-08 | 0.0013 | 0.018 | 0.047 | 0.081 | 0.16 | 0.21 | 0.16 | 0.11 | 0.084 | 0.065 | 0.027 | 0.016 | 0.011 | 0.0079 | 0.0032 |
| FLORIDA | | | | | | | | | | | | | | | | | |
| 10 | 3 | 2.970 | 5.510 | 4.530 | 3.590 | 3.050 | 2.440 | 2.050 | 1.040 | 0.629 | 0.427 | 0.315 | 0.1180 | 0.0663 | 0.0439 | 0.0323 | 0.0128 |
| 20 | 3 | 0.2370 | 1.460 | 1.910 | 1.810 | 1.610 | 1.310 | 1.170 | 0.693 | 0.445 | 0.313 | 0.234 | 0.0910 | 0.0518 | 0.0345 | 0.0255 | 0.0101 |
| 45 | 3 | 3E-04 | 0.0922 | 0.2920 | 0.393 | 0.421 | 0.396 | 0.361 | 0.275 | 0.214 | 0.1690 | 0.1350 | 0.0604 | 0.0360 | 0.0246 | 0.0184 | 0.0075 |
| 10 | 16 | 0.0385 | 0.595 | 1.010 | 1.100 | 1.080 | 0.950 | 0.879 | 0.627 | 0.444 | 0.330 | 0.255 | 0.1060 | 0.0615 | 0.0415 | 0.0308 | 0.0124 |
| 20 | 16 | 0.0023 | 0.1360 | 0.373 | 0.526 | 0.593 | 0.582 | 0.545 | 0.416 | 0.311 | 0.239 | 0.1880 | 0.0812 | 0.0479 | 0.0325 | 0.0242 | 0.0098 |
| 45 | 16 | 5E-07 | 0.0050 | 0.0421 | 0.1000 | 0.1480 | 0.199 | 0.205 | 0.167 | 0.144 | 0.1230 | 0.1040 | 0.0525 | 0.0327 | 0.0228 | 0.0173 | 0.0072 |

(1) CONCENTRATION FOR SECTOR WHERE MAXIMUM CONCENTRATION OCCURS
SOURCE = 1 g/s
STACK EXIT TEMPERATURE = 322 K
STACK DIAMETER = 1 m
RURAL CONDITIONS



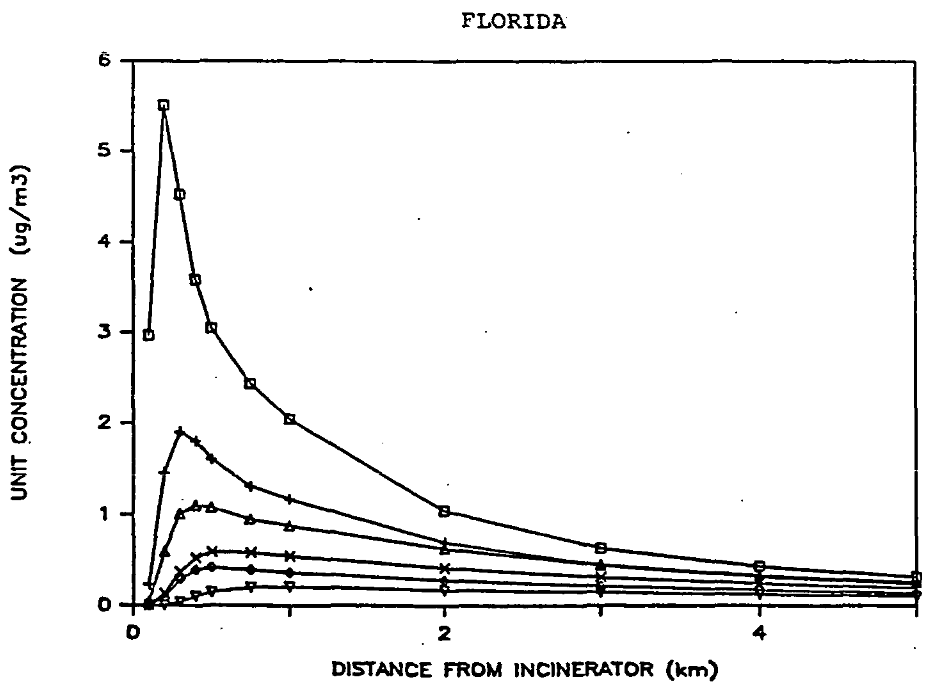




Figure 3.2 ISCLT unit concentrations.

Stack gas exit velocity = 3 m/s

Chemical = cadmium

Chemical concentration in sludge = 88.13 mg/kg (worst case)

Fraction emitted from stack = Ø.4 (worst case)

Receptor located Ø.2 km from the incinerator (unit concentration = 6.25)

AC = (1.157E-5) * (3ØØ) * (88.13) * (Ø.4) * (6.25)

AC = Ø.76 $\mu g/m^3$

## SECTION 4.Ø

## ISCLT ATMOSPHERIC DISPERSION MODEL

### 4.1 MODEL DESCRIPTION

The ISCLT (Industrial Source Complex Long-Term) (Bowers et al., 1979) dispersion model can be used to assess the air quality impacts of emissions from the incineration of sludge. The model is a sector-averaged model that extends and combines basic features of the Air Quality Display Model (AQDM) and the Climatological Dispersion Model (CDM). The long-term model uses statistical wind summaries to calculate seasonal (quarterly) and/or annual ground-level concentration or deposition values. ISCLT uses either a polar or a Cartesian receptor grid.

The major features of ISCLT are:

- Plume rise due to momentum and buoyancy as a function of downwind distance for stack emissions
- Procedures suggested by Huber and Snyder for evaluating building wake effects
- Procedures suggested by Briggs for evaluating stack-tip down-wash
- Separation of multiple point sources
- Consideration of the effects of gravitational settling and dry deposition on ambient particulate concentrations
- Capability of simulating line, volume and area sources
- Capability to calculate dry deposition
- Variation with height of wind speed (wind-profile exponent law)
- Concentration estimates for 1-hour to annual average
- Terrain-adjustment procedures for complex terrain
- Consideration of time-dependent exponential decay of pollutants

## 4.2 MODEL INPUT DATA AND PARAMETERS

The input requirements for the ISC Model long-term computer program (ISCLT) consist of four categories:

- Meteorological data
- Source data
- Receptor data
- Program control parameters

Each of these data categories is discussed separately below.

### 4.2.1 Meteorological Data

Seasonal or annual "STAR" summaries (statistical tabulations of the joint frequency of occurrence of wind-speed and wind-direction categories, classified according to the Pasquill stability categories) are the principal meteorological inputs to ISCLT. The program accepts STAR summaries with six Pasquill stability categories (A through F) or five stability categories (A through E with the E and F categories combined). ISCLT is not designed to use the Climatological Dispersion Model (CDM) STAR summaries which subdivide the neutral D stability category into day and night D categories. Additional meteorological data requirements include seasonal average maximum and minimum mixing heights and ambient air temperatures. These data are contained in STAR summary data sets for a large number of locations in the U.S.; and are accessible online.

### 4.2.2 Source Data

The ISCLT program accepts three source types: stack, area, and volume. For each source, input data requirements include the source location with respect to a user-specified origin, the source elevation (if terrain effects are to be included in the model calculations), and the pollutant emission rate. For each stack, additional source input requirements include the physical stack height, the stack inner diameter, the stack exit temperature, the stack exit velocity, and -- if the stack is adjacent to a building and aerodynamic wake effects are to be considered -- the length, width and height of the building. Table 4.1 lists the ISCLT source input parameters for stacks.

TABLE 4.1 ISCLT SOURCE INPUT DATA FOR STACKS

| DATA TYPE | UNITS | COMMENT |
|---|---|---|
| Pollutant Emission Rate | g/s | Unit Rate (=1.) |
| Pollutant Decay Coefficient | $s^{-1}$ | Assumed = Ø |
| Elevation of Base of Stack | m | Assumed = Ø |
| Stack Height | m | See Section 2.2 |
| Stack Inner Diameter | m | See Section 2.2 |
| Stack Exit Temperature | deg K | See Section 2.2 |
| Stack Exit Velocity | m/s | See Section 2.2 |
| Gravitational Settling Data | - | Not used |
| Adjacent Building Dimensions | - | Not used |

In the cases of area and volume sources, the horizontal dimensions and effective emission height are required for each source. If the calculations are to consider particulates with appreciable gravitational settling velocities, source inputs for each source also include the mass fraction of particulates in each gravitational settling-velocity category as well as the surface reflection coefficient and settling velocity of each settling-velocity category. Because industrial pollutant emission rates are often highly variable, emission rates for each source may be held constant or varied.

### 4.2.3 Receptor Data

The ISCLT program uses either a polar (r, $\theta$ ) or a Cartesian (X, Y) coordinate system. The typical polar receptor array consists of 36 radials (one for every 10 degrees of azimuth) and five to ten downwind ring distances for a total of 180 to 360 receptors. However, the user is not restricted to a 10-degree angular separation of receptors. Receptor locations in the Cartesian coordinate system may be given as Universal Transverse Mercator (UTM) coordinates or as X (east-west) and Y (north-south) coordinates with respect to a user-specified origin. Discrete receptor points corresponding to the locations of air quality monitors, elevated terrain, or other points of interest may also be used with either coordinate system. If terrain effects are to be included in the calculations, the elevation of each receptor is also required.

In this methodology, a polar coordinate receptor network is used which consists of sixteen compass direction sectors and ring distances of 0.6, 1, 2, 3, 4, 5, 10, 15, 25, and 50 km.

### 4.2.4 Program Control Parameters and Options

A number of user controlled parameters and options are available to allow the user to select specific types of analyses and results. Some of the analysis options are:

- calculate average concentration or total deposition
- selection of a cartesian or a polar receptor grid system
- specification of an elevation for each receptor (level terrain is assumed by the program otherwise)
- make calculations for either urban or rural mode

- compute plume rise as either a function of downwind distance or for all distances
- vary emissions by season, wind speed, and/or Pasquill stability category
- evaluate stack-tip downwash for all sources using the Briggs procedures

## SECTION 5.Ø

## REFERENCES

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